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The Vermont Department of Health (Health) develops and maintains two sets of chemical-specific screening values, Risk Based-Residential Air Screening Levels (RB-RASLs) and Risk Based-Nonresidential Air Screening Levels (RB-NASLs), which may be used in the evaluation of potential exposure to chemicals in indoor air. RB-RASLs are appropriate for consideration in the assessment of potential residential exposure to chemicals in indoor air. RB-NASLs are appropriate for consideration in the assessment of potential exposure to chemicals in indoor air under a hypothetical nonresidential exposure scenario.

The 2017 list of chemicals examined and associated screening values are presented in Attachment 1. Additional chemicals may be considered for evaluation and potential inclusion based on request by other State of Vermont offices, in response to public comments or as deemed appropriate by Health.

A detailed summary of toxicity values employed, endpoint-specific risk-based concentrations and any chemical-specific notes of interest is presented in Attachment 2.

In addition, a brief chemical-specific monograph summarizing the information available for review, scenario-specific screening value and derivation thereof is prepared. Any variance from the general process is noted.

Each screening value is based upon the best available information at the time of derivation; therefore, is subject to change as updated information and risk assessment methodologies become available.

This memo provides an overview of the general approach used to develop the 2017 RB-RASLs and RB-NASLs and how these values are recommended to be applied.

RB-RASL and RB-NASL DERIVATION PROCESS AND APPLICATION

In general, RB-RASLs are generated by combining current toxicity values (e.g., inhalation reference concentrations and inhalation unit risks) with a hypothetical residential exposure scenario using standard point estimate risk assessment procedures to derive an estimate of the concentration of each individual chemical in indoor air that corresponds to a fixed level of risk i.e., a target Hazard Quotient (THQ) of 0.1 for noncarcinogenic (systemic, threshold) effects or a target incremental lifetime cancer risk (ILCR) of one-in-one million (1×10^{-6}).

Similarly, RB-NASLs are generated by combining current toxicity values (e.g., inhalation reference concentrations and inhalation unit risks) with a hypothetical nonresidential exposure scenario using standard point estimate risk assessment procedures to derive an estimate of the concentration of each



individual chemical in indoor air that corresponds to a fixed level of risk i.e., a THQ of 0.1 for noncarcinogenic (systemic, threshold) effects or a target ILCR of 1×10^{-6} .

For each scenario, where a chemical is known to have both noncarcinogenic and carcinogenic effects and toxicity values are available, a value is derived based on each endpoint with the most conservative reported as the screening value for that chemical under that scenario. Thus, the most conservative value derived for each chemical based on the residential scenario is reported as the RB-RASL for that chemical. Likewise, the most conservative value derived for each chemical based on the nonresidential scenario is reported as the RB-NASL for that chemical.

In those instances where screening values are based upon carcinogenic effects, if more than one chemical is reported in excess of its analytical laboratory reporting limit, it is recommended that a receptor and medium-specific cumulative (total) ILCR be estimated (i.e., a Residential Air or Nonresidential Air cumulative ILCR) and compared to a target cumulative ILCR of 1×10^{-6} . This can be accomplished using the following approach where i represents the i^{th} such chemical reported in indoor air and, as described above, the target ILCR associated with each cancer based indoor air screening level (SL) is 1×10^{-6} :

$$MediumCumulativeILCR_{(Residential\ or\ Nonresidential)} = \sum_{i=1}^n (SiteConcentration_i)(1 \times 10^{-6}) / (Residential\ or\ Nonresidential\ SL_i) \cdot$$

A receptor and medium-specific cumulative ILCR in excess of 1×10^{-6} indicates a closer look at the medium in question or further consideration is warranted.

If more than one environmental medium is under investigation, it is recommended that medium-specific ILCRs for the same hypothetical receptor (e.g., Hypothetical Resident) be summed to yield a receptor-specific estimate of total site ILCR. A receptor-specific total site ILCR in excess of 1×10^{-6} indicates a closer look at the area in question or further consideration is warranted.

A target Hazard Quotient of 0.1 is used in the development of each noncancer (systemic, threshold) based screening level as simultaneous exposure to more than one chemical in indoor air and/or exposure to the same chemical, or other chemicals, in other environmental media could result in a Hazard Index (HI) in excess of the target HI of 1 (HI is the sum of two or more Hazard Quotients).

Direct exposure via inhalation of indoor air is the only route of exposure considered in the development of RB-RASLs and RB-NASLs. These evaluations do not take into account potential existing concentrations of these chemicals in either indoor or ambient air.

Toxicity

Toxicity information and inhalation and oral toxicity values are obtained and reviewed from a number of relevant and appropriate sources including:

- U.S. Environmental Protection Agency (EPA) Integrated Risk Information System
- U.S. EPA Office of Pesticide Programs
- U.S. EPA Office of Research and Development/National Center for Environmental Assessment / Superfund Health Risk Technical Support Center (STSC) Provisional Peer Reviewed Toxicity Values
- International Agency for Research on Cancer
- National Toxicology Program
- California EPA Office of Environmental Health Hazard Assessment
- California Department of Pesticide Regulation

- Agency for Toxic Substances and Disease Registry

Mutagenic Mode of Action

Consistent with U.S. EPA guidance (EPA, 2005), multipliers termed Age Dependent Adjustment Factors (ADAFs) are used in the evaluation of carcinogens identified by U.S. EPA to operate via a mutagenic mode of action. Such chemicals are noted in the detailed Summary Table (Attachment 2). Per the guidance, ADAFs “...reflect the potential for early-life exposure to make a greater contribution to the cancers appearing later in life.”

Chemical-specific ADAFs are used if available.

Otherwise, the following non-chemical specific, default adjustments provided by U.S. EPA are employed:

- A 10 fold increase for exposures between the day of birth up until the second birthday.
- A 3 fold increase for exposures between the second birthday up until the sixteenth birthday.
- No adjustment is made for exposures occurring after turning 16 years of age.

Exposure

Several conservative assumptions are made in order to estimate the potential intake of a chemical in indoor air by a hypothetical receptor. In reality, the magnitude and frequency of exposure will vary depending on individual circumstances. The use of such health protective assumptions, which tend to represent reasonable upper bound estimates of exposure, adds additional conservatism to the two sets of screening values derived.

Overall, for the residential scenario, a 70 year time-weighted approach (birth to age 70 years) is employed in the assessment of carcinogens. Continual exposure is assumed.

For the nonresidential scenario, a hypothetical adult is assumed to be on-site 10 hours per day (BLS, 2016), 250 days per year (EPA, 1991) for 30 years. A 70 year lifetime is assumed. A 30 year time-weighted approach is employed in the assessment of carcinogens.

A summary of exposure assumptions and factors employed in the development of the 2017 RB-RASLs and RB-NASLs is presented in Attachment 3.

Equations

Endpoint and exposure route specific equations used in development of the 2017 RB-RASLs and RB-NASLs are presented in Attachment 4. These equations combine chemical-specific toxicity information with scenario-specific exposure assumptions to generate a level in indoor air estimated to correspond to a fixed level of risk i.e., a THQ of 0.1 or ILCR of 1×10^{-6} .

REFERENCES

BLS, 2016. United States Bureau of Labor Statistics. Division of Labor Force Statistics. Labor Force Statistics from the Current Population Survey. Household Data Annual Average. Last modified February 8, 2017. Accessed 3/28/2017) <https://www.bls.gov/cps/cpsaat19.htm>

EPA, 1991. Human Health Evaluation Manual, Supplemental Guidance: "Standard Default Exposure Factors". United States Environmental Protection Agency. Office of Solid Waste and Emergency Response. OSWER Publication 9285.6-03. March 1991.

EPA, 2005. Supplemental Guidance for Assessing Susceptibility from Early-Life Exposure to Carcinogens. U.S. Environmental Protection Agency. Washington, D.C. EPA/630/R-03/003F. March 2005.

ATTACHMENT 1**VERMONT DEPARTMENT OF HEALTH****2017 RISK BASED-RESIDENTIAL AIR SCREENING LEVELS (RB-RASLs) ($\mu\text{g}/\text{m}^3$)****2017 RISK BASED-NONRESIDENTIAL AIR SCREENING LEVELS (RB-NASLs) ($\mu\text{g}/\text{m}^3$)**

Analyte	CAS Number	RB-RASL ($\mu\text{g}/\text{m}^3$)	Endpoint	RB-NASL ($\mu\text{g}/\text{m}^3$)	Endpoint
Benzene	71-43-2	0.13	c	1.05	c
Naphthalene	91-20-3	0.03	c	0.24	c
Tetrachloroethylene	127-18-4	0.63	c	5.11	c
Trichloroethylene	79-01-6	0.20	c:non-mmoa &mmoa	0.70	nc
Vinyl chloride	75-01-4	0.11	c-mmoa	1.86	c

Notes:

c - Screening level corresponds to a one-in-one-million incremental lifetime cancer risk

mmoa - carcinogen identified by U.S. EPA to operate via mutagenic mode of action

nc - Screening level corresponds to a noncancer Hazard Quotient of 0.1

non-mmoa - carcinogenic but not identified by U.S. EPA to operate via mutagenic mode of action

ATTACHMENT 2
VERMONT DEPARTMENT OF HEALTH
DETAILED SUMMARY TABLE
2017 RISK BASED-RESIDENTIAL AIR SCREENING LEVELS (RB-RASLs) (ug/m³)
2017 RISK BASED-NONRESIDENTIAL AIR SCREENING LEVELS (RB-NASLs) (ug/m³)

Chemical Name	CAS No.						Residential - Indoor Air				Nonresidential - Indoor Air				
							Cancer Target Risk = 1x10 ⁻⁶		Noncancer Hazard Quotient = 0.1		RB-RASL		Cancer Target Risk = 1x10 ⁻⁶		Noncancer Hazard Quotient = 0.1
		IUR (µg/m ³) ⁻¹	Ref	RfC mg/m ³	Ref	mmoa	Inhalation µg/m3	Inhalation µg/m3	µg/m3	endpoint			Inhalation µg/m3	Inhalation µg/m3	µg/m3
Benzene	71-43-2	7.80E-06	(a)	3.00E-02	I	--	0.13	3.00	0.13	c		1.05	10.51	1.05	c
Naphthalene	91-20-3	3.40E-05	CE	3.00E-03	I	--	0.03	0.30	0.03	c		0.24	1.05	0.24	c
Tetrachloroethylene	127-18-4	1.60E-06	(b)	4.00E-02	I	--	0.63	4.00	0.63	c		5.11	14.02	5.11	c
Trichloroethylene (non-mmoa/ mmoa)	79-01-6	3.1E-06/1.0E-06	I	2.00E-03	I	c:non-mmoa&mmoa	0.20	0.20	0.20	c		1.99	0.70	0.70	nc
Vinyl chloride	75-01-4	8.80E-06 (c)	I	1.00E-01	I	mmoa	0.11	10.00	0.11	c		1.86	35.04	1.86	c

NOTES:

c - screening level corresponds to a one-in-one-million incremental lifetime cancer risk

CAS No. - Chemical Abstracts Service Registration Number

CE - California Environmental Protection Agency

I - U.S. EPA Integrated Risk Information System

IUR - Inhalation Unit Risk

mmoa - carcinogen identified by U.S. EPA to operate via mutagenic mode of action

nc - screening level corresponds to a noncarcinogenic Hazard Quotient of 0.1

non-mmoa - carcinogenic but not identified by U.S. EPA to operate via a mutagenic mode of action

RB-NASL - Risk Based-Nonresidential Air Screening Level

RB-RASL - Risk Based-Residential Air Screening Level

RfC - Inhalation Reference Concentration

Ref - References

(a) Benzene - Most conservative end of range of Inhalation Unit Risks presented in IRIS citation dated 1/19/00 [2.2E-06 to 7.8E-06 (µg/m³)⁻¹]

(b) Tetrachloroethylene -Geometric mean of Inhalation Unit Risks presented in IRIS citation dated 2/10/12 [2.6E-07 (µg/m³)⁻¹ based on hepatocellular adenoma/carcinoma & 1E-05 (µg/m³)⁻¹ based on mononuclear cell leukemia]

(c) Vinyl chloride - Inhalation Unit Risk of 4.4E-06 (ug/m³)⁻¹ based on continuous lifetime exposure during adulthood used to develop cancer based screening level for Nonresidential - Indoor Air

ATTACHMENT 3
VERMONT DEPARTMENT OF HEALTH
EXPOSURE ASSUMPTIONS, PARAMETER VALUES AND FACTORS
2017 RISK BASED-RESIDENTIAL AIR SCREENING LEVELS (RB-RASLs)
2017 RISK BASED-NONRESIDENTIAL AIR SCREENING LEVELS (RB-NASLs)

SYMBOL	DEFINITION (units)	VALUE	REFERENCE
RB-RASL	Risk Based-Residential Air Screening Level ($\mu\text{g}/\text{m}^3$)	Chemical-Specific	Attachments 1, 2, 4
RASL _{nc-inh}	Resident, Air, Noncancer, Inhalation ($\mu\text{g}/\text{m}^3$)	Chemical-Specific	Attachments 4
RASL _{ca-inh}	Resident, Air, Cancer, Inhalation ($\mu\text{g}/\text{m}^3$)	Chemical-Specific	Attachments 4
RASL _{m-inh}	Resident, Air, Mutagenic, Inhalation ($\mu\text{g}/\text{m}^3$)	Chemical-Specific	Attachments 4
RB-NASL	Risk Based-Nonresidential Air Screening Level ($\mu\text{g}/\text{m}^3$)	Chemical-Specific	Attachments 1, 2, 4
NASL _{nc-inh}	Nonresidential, Air, Noncancer, Inhalation ($\mu\text{g}/\text{m}^3$)	Chemical-Specific	Attachments 4
NASL _{ca-inh}	Nonresidential, Air, Cancer, Inhalation ($\mu\text{g}/\text{m}^3$)	Chemical-Specific	Attachments 4
RfC	Chronic Inhalation Reference Concentration (mg/m^3)	Chemical-Specific	Attachment 2
IUR	Inhalation Unit Risk ($\mu\text{g}/\text{m}^3$) ⁻¹	Chemical-Specific	Attachment 2
THQ	Target Hazard Quotient (unitless)	0.1	See Text
TR	Target Incremental Lifetime Cancer Risk (unitless)	1×10^{-6}	See Text
LT	Lifetime (years)	70	EPA, 1989
AT _{R-ca}	Averaging Time, Resident, Cancer (days)	$365 \times \text{ED}_R = 25550$	Calculated
AT _{N-nc}	Averaging Time, Nonresidential, Noncancer (days)	$365 \times \text{ED}_N = 10950$	Calculated
AT _{N-ca}	Averaging Time, Nonresidential, Cancer (days)	$365 \times \text{ED}_N = 25550$	Calculated
EF _R	Resident Exposure Frequency (days/year)	365	See Text
EF _{Birth-<2yr}	Resident Exposure Frequency, Fine Age Range Child _{Birth-<2years} (days/year)	365	See Text
EF _{2-<6yr}	Resident Exposure Frequency, Fine Age Range Child _{2-<6years} (days/year)	365	See Text
EF _{6-<16yr}	Resident Exposure Frequency, Fine Age Range Child _{6-<16years} (days/year)	365	See Text
EF _{16-<18yr}	Resident, Exposure Frequency, Fine Age Range Child _{16-<18years} (days/year)	365	See Text
EF _A	Resident Exposure Frequency, Adult (days/year)	365	See Text
EF _N	Nonresidential Exposure Frequency (days/year)	250	EPA, 1991
ED _R	Resident Exposure Duration (years)	70	See Text
ED _{Birth-<2yr}	Resident Exposure Duration, Fine Age Range Child _{Birth-<2years} (years)	2	Calculated
ED _{2-<6yr}	Resident Exposure Duration, Fine Age Range Child _{2-<6years} (years)	4	Calculated
ED _{6-<16yr}	Resident Exposure Duration, Fine Age Range Child _{6-<16years} (years)	10	Calculated
ED _{16-<18yr}	Resident Exposure Duration, Fine Age Range Child _{16-<18years} (years)	2	Calculated
ED _A	Resident Exposure Duration, Adult (years)	52	Calculated
ED _N	Nonresidential Exposure Duration (years)	30	(a)
ET _R	Resident Exposure Time (hours/day)	24	EPA, 2016
ET _{Birth-<2yr}	Resident Exposure Time, Fine Age Range Child _{Birth-<2years} (hours/day)	24	EPA, 2016
ET _{2-<6yr}	Resident Exposure Time, Fine Age Range Child _{2-<6years} (hours/day)	24	EPA, 2016
ET _{6-<16yr}	Resident Exposure Time, Fine Age Range Child _{6-<16years} (hours/day)	24	EPA, 2016
ET _{16-<18yr}	Resident Exposure Time, Fine Age Range Child _{16-<18years} (hours/day)	24	EPA, 2016
ET _A	Resident Exposure Time, Adult (hours/day)	24	EPA, 2016
ET _N	Nonresidential Exposure Time (hours/day)	10	BLS, 2016
IFAM _{R-adj}	Resident Mutagenic Air Inhalation Factor, age-adjusted (hours)	1,016,160	Attachment 4

Notes:

(a) General estimate of years of service for full benefits

References:

BLS, 2016. United States Bureau of Labor Statistics. Division of Labor Force Statistics. Labor Force Statistics from Current Population Survey. Household Data. Annual Average. Last modified February 8, 2017 (accessed 3/28/2017) <https://www.bls.gov/cps/cpsaat19.htm>.

EPA, 1989. Risk Assessment Guidance for Superfund. Volume I: Human Health Evaluation Manual (Part A). Interim Final. United States Environmental Protection Agency. Office of Emergency and Remedial Response. Washington, D.C. EPA/540/1-89/002. December 1989.

EPA, 1991. Human Health Evaluation Manual, Supplemental Guidance: "Standard Default Exposure Factors". United States Environmental Protection Agency. Office of Solid Waste and Emergency Response. OSWER Publication 9285.6-03. March 1991.

EPA, 2016. United States Environmental Protection Agency. Regional Screening Levels for Chemical Contaminants at Superfund Sites. User's Guide. May 2016 edition. (accessed June 6, 2016). <https://www.epa.gov/risk/regional-screening-levels-rsls>.

ATTACHMENT 4
VERMONT DEPARTMENT OF HEALTH
SCENARIO, ENDPOINT AND PATHWAY SPECIFIC EQUATIONS
2017 RISK BASED-RESIDENTIAL AIR SCREENING LEVELS
2017 RISK BASED-NONRESIDENTIAL AIR SCREENING LEVELS

I. RISK BASED-RESIDENTIAL AIR SCREENING LEVELS

- **Noncarcinogenic (threshold type, systemic effects)**

Risk Based-Residential Air Screening Level

- o Inhalation (simplified equation)

$$RASL_{nc-inh}(\mu g/m^3) = INHALATION\ REFERENCE\ CONCENTRATION\ (\mu g/m^3) * THQ$$

- **Carcinogenic**

Risk Based-Residential Air Screening Level

- o Inhalation

$$RASL_{ca-inh}(\mu g/m^3) = \frac{TR * AT_{R-ca} \left(\frac{365\ days}{year} * LT\ (70\ years) \right)}{IUR(\mu g/m^3)^{-1} * EF_R \left(\frac{365\ days}{year} \right) * ED_R(70\ years) * ET_R \left(\frac{24\ hours}{day} * \frac{1\ day}{24\ hours} \right)}$$

- **Carcinogenic via Mutagenic Mode of Action and Default ADAFs used**

Risk Based-Residential Air Screening Level

- o Inhalation

$$RASL_{m-inh}(\mu g/m^3) = \frac{TR * AT_{R-ca} \left(\frac{365\ days}{year} * LT\ (70\ years) \right)}{IUR(\mu g/m^3)^{-1} * \left(\frac{1\ day}{24\ hours} \right) * IFAM_{R-adj}(1,016,160\ hours)}$$

Where:

IFAM_{R-adj} (1,016,160 hours) =

$$\begin{aligned} & [ET_{Birth-<2yr} \left(\frac{24\ hours}{day} \right) * EF_{Birth-<2yr} \left(\frac{365\ days}{year} \right) * ED_{Birth-<2yr}(2\ years) * 10] + \\ & [ET_{2-<6yr} \left(\frac{24\ hours}{day} \right) * EF_{2-<6yr} \left(\frac{365\ days}{year} \right) * ED_{2-<6yr}(4\ years) * 3] + \\ & [ET_{6-<16yr} \left(\frac{24\ hours}{day} \right) * EF_{6-<16yr} \left(\frac{365\ days}{year} \right) * ED_{6-<16yr}(10\ years) * 3] + \\ & [ET_{16-<18yr} \left(\frac{24\ hours}{day} \right) * EF_{16-<18yr} \left(\frac{365\ days}{year} \right) * ED_{16-<18yr}(2\ years) * 1] + \\ & [ET_A \left(\frac{24\ hours}{day} \right) * EF_A \left(\frac{365\ days}{year} \right) * ED_A(52\ years) * 1] \end{aligned}$$

II. RISK BASED-NONRESIDENTIAL AIR SCREENING LEVELS

- **Noncarcinogenic (threshold type, systemic effects)**

Risk Based-Nonresidential Air Screening Level

- o Inhalation

$$NASL_{nc-inh}(\mu g/m^3) = \frac{THQ * AT_{N-nc} \left(\frac{365 \text{ days}}{\text{year}} * ED_N(30 \text{ years}) \right) * \left(\frac{1000 \mu g}{mg} \right)}{\frac{1}{RfC(\frac{mg}{m^3})} * EF_N \left(\frac{250 \text{ days}}{\text{year}} \right) * ED_N(30 \text{ years}) * ET_N \left(\frac{10 \text{ hours}}{\text{day}} * \frac{1 \text{ day}}{24 \text{ hours}} \right)}$$

- **Carcinogenic**

Risk Based-Nonresidential Air Screening Level

- o Inhalation

$$NASL_{ca-inh}(\mu g/m^3) = \frac{TR * AT_{N-ca} \left(\frac{365 \text{ days}}{\text{year}} * LT(70 \text{ years}) \right)}{IUR(\mu g/m^3)^{-1} * EF_N \left(\frac{250 \text{ days}}{\text{year}} \right) * ED_N(30 \text{ years}) * ET_N \left(\frac{10 \text{ hours}}{\text{day}} * \frac{1 \text{ day}}{24 \text{ hours}} \right)}$$